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ORIGINAL ARTICLE

Can we improve radiological analysis of osseous lesions in chronic anterior shoulder instability?

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KEYWORDS

Anterior shoulder
 instability;
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 Reproducibility

Summary Osseous lesions of the glenoid cavity and humeral head are predictive of recurrence after Bankart arthroscopic procedures. The objective of this study was to analyze, for each glenoid and humeral defect plain x-ray criteria of the Instability Severity Index Score (ISIS), two aspects: inter- and intraobserver reliability of their qualitative and quantitative assessment and correlations between positive criteria and their quantitative measurement. Thirty-one medical files were retained for evaluation of the glenoid and 26 for humeral notch assessment. The yes or no response for the ISIS criterion was completed by its quantitative measurement using the Griffiths and Sugaya CT methods for the glenoid and the P/R index calculation on plain x-rays with internal rotation for the Hill-Sachs lesion. Three observers provided two consecutive readings for each criterion. The analysis of the glenoid radiological criterion of the ISIS seems sufficiently reproducible for daily practice. When the evaluation is positive, bone loss is greater than 15%, without a maximum value established. In this study, the analysis of the ISIS humeral notch criterion was not reproducible. It can be improved using the P/R index and should be completed by CT imaging.

Level of evidence: Level IV: retrospective diagnostic study.

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1. Introduction

The traumatic notch of the humeral head was anatomically designated by Malgaigne in 1855 [1], then Hill and Sachs described its radiography in 1940 (Hill-Sachs lesion, HSL) [2], followed by the description of glenoid rim lesions [3–5]. The role of these bony lesions in recurrence of shoulder

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Figure 1 Visibility of humeral head Hill-Sachs lesion on AP x-ray in three rotations: internal (a), neutral (b), and maximum external (c). In this case, the lesion remains visible on the maximum external rotation view and counts for two points out of 10 on the ISIS. It should be noted that the notch defect is visible here in terms of both loss of humeral head bone substance and depth condensation.

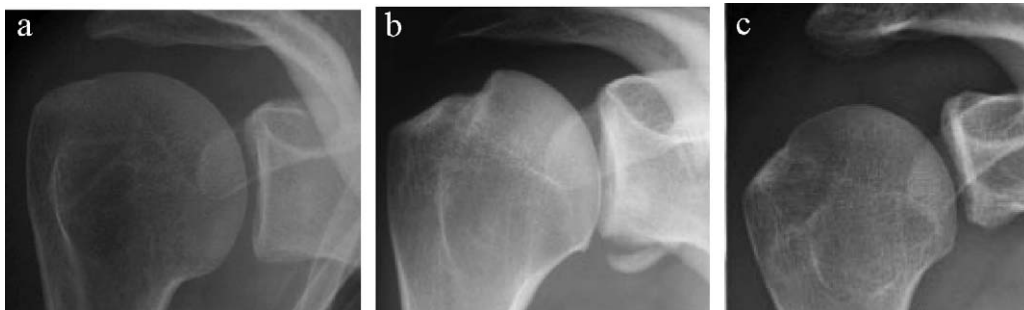


Figure 2 Visibility of the glenoid bony lesion on the plain AP x-ray with from left to right: no lesion (a), fracture (b), erosion (c). The visibility criterion is loss of continuity of the subchondral sclerotic contour.

instability, whether or not it had been treated surgically, was first suspected clinically [6–8] and then proven in the laboratory [9–11]. More recently, these lesions have been demonstrated to be predictive of recurrence after Bankart arthroscopic procedures [12–14]. Their diagnosis and quantification therefore participate in the choice of the surgical technique: anterior pedicled bone or osteomuscular transplantation in cases of glenoid insufficiency [15] or filling the humeral bony defect when it is deemed voluminous [16]. For the glenoid, the value of 25% destroyed surface has been reported in a number of publications as the quantitative threshold requiring transplantation. This value was set based on experimental [17,18], arthroscopic [19], and radiographic studies. For the radiographic studies, the authors agree on the distinction between avulsion, fracture-separation, and erosion of the glenoid rim [14,20], but there was no consensus on the quantitative assessment methodology. Certain authors suggest two- or three-dimensional CT reconstruction techniques [21–23]. Evaluation of the HSL poses additional problems related to the three-dimensional aspect of the humeral sphere, its retroversion, and its rotational position during image taking. Classically, it is more visible in internal rotation, but its visibility criteria have not been clearly defined; nor has the technique for volume, surface area, and location measurement [24,25]. The humeral engaging lesion stems from empirical appreciations and has not really been demon-

strated on living tissue [19]. The surgeon is therefore faced with a costly and time-consuming radiological escalation. Balg and Boileau have suggested simplifying the analysis of these osseous lesions by assessing them semi-quantitatively with a standard radiographic workup. The therapeutic indications score, the ISIS (Instability Severity Index Score), considers an HSL defect to be important if it remains visible on the AP image with maximum external rotation (Fig. 1), and a glenoid lesion is identified if it shows loss of the subchondral sclerotic contour (Fig. 2) [26]. These two criteria tally two points out of a score of ten points, with the authors considering 3 points the limit above which Bankart arthroscopic repair is contraindicated [15]. The reliability of the evaluation of these criteria is therefore high since they account for 40% of the indication in the choice of a technique in this methodology. The objective of this study was to analyze two aspects for each of two criteria – glenoid and humeral notch defect – on the ISIS: inter- and intraobserver reliability of their qualitative and quantitative assessment and the correlations between positive findings for these criteria and their quantitative measurement.

2. Material and methods

Fifty-seven radiological files were selected based on technical success criteria within a multicenter clinical study

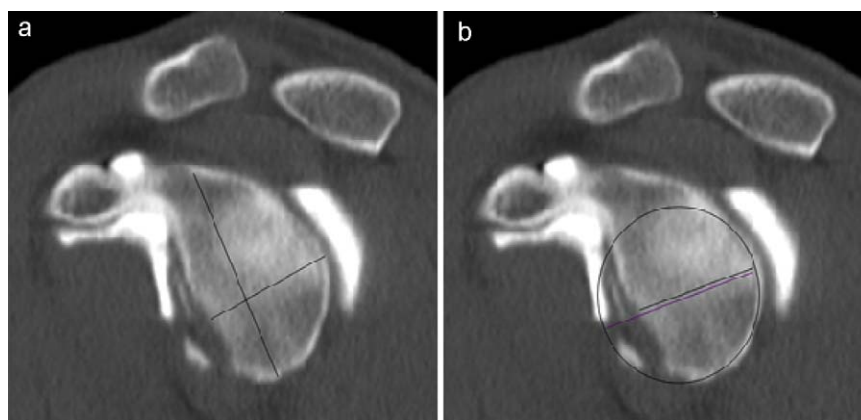


Figure 3 Quantitative measurement of glenoid bone substance by reconstruction of the sagittal en-face view. The Griffiths Index (a) measures the ratio of the remaining glenoid width and its height, and the Sugaya Index (b) measures the ratio of the remaining glenoid width and its diameter [21,22]. In both, the normal value is close to 1.

conducted by the French Arthroscopy Society in 2009. Thirty-one files were retained for glenoid assessment. Each selected file had a standard AP radiograph in neutral rotation perfectly visualizing the glenohumeral joint space and a CT arthrogram. The qualitative assessment was based on the yes or no response to the criterion of subchondral sclerotic contour loss (Fig. 2). The quantitative evaluation required multiplanar reconstruction using the Osirix® 3.5.1 software (Geneva, Switzerland), including the calculation of the Griffith and Sugaya indexes on the en-face view of the sagittal glenoid reconstruction [21,22] (Fig. 3). Twenty-six files were used to analyze the HSL defect. They included three AP images in rotation: internal (hand on the stomach), neutral (condensation of the internal side of the lesser tubercle visible on the external third of the metaphysis), and maximal external (relief of the lesser tubercle extending outside the external cortex of the metaphysis). The qualitative appreciation was based on the yes or no response to the criterion of bone loss in the humeral head contour in maximal external rotation (Fig. 1). Evaluation of the depth of the lesion was based on the P/R index calculation where P measures the depth of the notch and R the radius of the humeral head on the internal rotation x-rays (Fig. 4) [24]. The radius was measured using templates of progressive diameters superimposed on the humeral head contour, automatically providing the R-value. The millimetric measurements were then used to calculate the P/R ratio to solve the problems of radiographic enlargement. For the glenoid, the images were read by three senior operators (two surgeons and one radiologist) and for the notch defect by one junior and two senior operators, all three surgeons. The images were read at least 15 days apart. The calculations of inter- and intraobserver agreement used the Kappa-Feiss and Kappa-Cohen tests and the intraclass correlation tests (ICCT) [27]. The quality of the agreement was calculated as indicated in Table 1 and the significance level set at $P=0.05$. The statistical relations between the qualitative (yes/no) and quantitative evaluations were based on the Mann-Whitney test and the calculation of the threshold value beyond which these relations were reliable used the receiver operating characteristic (ROC) curves.

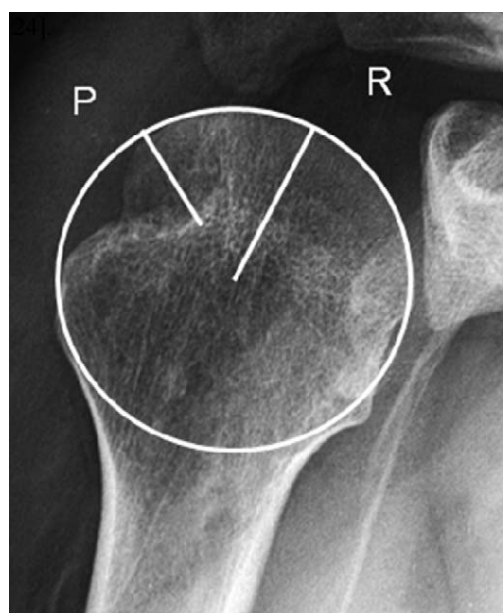


Figure 4 Quantitative measurement of the depth of the Hill-Sachs lesion using the calculation of the P/R ratio between the maximum depth of the notch defect (P) in internal rotation interne and the radius (R) of the humeral head [24]. If there is no notch, the ratio is equal to 0 [24].

Table 1 Quality of intra- and interobserver agreement for Kappa-Feiss and Kappa-Cohen coefficients and intraclass correlations.

Coefficients	Quality of agreement
1–0.81	Excellent
0.80–0.61	Good
0.60–0.41	Moderate
0.40–0.21	Low
0.20–0	Very low
< 0	Poor

Table 2 Intra- and interobserver agreement for yes or no answers for the ISIS plain x-ray criteria.

	Interobserver	Intraobserver
Glenoid	First reading: 0.47 Second reading: 0.44	Reader A: 0.93 Reader B: 0.66 Reader C: 0.72
Hill-Sachs lesion	First reading: 0.30 Second reading: 0* ($P=0.8$)	Reader D: 0.92 Reader E: 0.49 Reader F: 0.06* ($p=0.7$)

Readers A and B: senior surgeons; C: senior radiologist; readers D and E: senior surgeons; F: junior surgeon. All P -values less than 0.005 except*.

3. Results

Inter- and intraobserver reliability of the yes or no response to the ISIS criteria of presence of a glenoid lesion or a visible HSL are reported in [Tables 2 and 3](#). The interobserver reliability was intermediate for the glenoid and low or very low for the HSL. The intraobserver reliability was good or excellent for the three observers evaluating the glenoid criterion and remained good or excellent for the two senior observers of the notch criterion but became low for the junior observer.

There was a significant relation between the yes or no response to the ISIS glenoid criterion and the Griffiths and Sugaya indexes, with the "yes" response corresponding to the quantitatively most severe lesions ([Fig. 5](#)). This relation appeared to be more significant for the Griffiths and Sugaya indexes; the value from which the "yes" response appeared reliable was in this case 0.85, corresponding to a 15% glenoid bone substance loss. Below this value, the qualitative and quantitative responses no longer presented significant relations. For the HSL, the mean value of the depth index (P/R) was 0.27 (range, 0–0.8; SD, 0.21), but no significant relation between the yes or no response to the ISIS visibility criterion and this value was demonstrated.

Table 3 Intra- et interobserver agreement for quantitative measurements of glenoid bone loss (Griffiths and Sugaya indexes) and the depth of the Hill-Sachs lesion (P/R index).

	Interobserver agreement	Intraobserver agreement
Griffiths Index	First reading: 0.71 Second reading: 0.68	Reader A: 0.9 Reader B: 0.9 Reader C: 0.78
Sugaya Index	First reading: 0.74 Second reading: 0.74	Reader A: 0.9 Reader B: 0.95 Reader C: 0.9
P/R Hill-Sachs lesion Index	First reading: 0.81 Second reading: 0.92	Reader D: 0.97 Reader E: 0.92 Reader F: 0.72

All P -values were lower than 0.005.

4. Discussion

The limitations of this study are first of all those of plain radiographs. Even though derived from a multicenter clinical study based partly on ISIS radiological criteria, only a limited number of files that met these technical success criteria could be retained, illustrating the reliability problems inherent to plain radiography from one center to another. The second limitation was the absence of a junior reader for the analysis of the glenoid criterion. Lack of experience seems to have influenced the qualitative radiological analysis (yes/no response) more than the quantitative measurements, standard for the calculation of the P/R ratio of the notch and computer-based for the Griffiths and Sugaya indexes. Calculation of these ratios was not compromised by the contrast agent used for the arthro-CTs.

The reliability of the ISIS analysis of the glenoid is mediocre between the observers and good for each of them. It is clearly less than that observed recently by Jankauskas et al. in a single-center study of 34 files of anterior instability patients with an agreement coefficient of 0.88 between two observers for the disappearance of the glenoid sclerotic

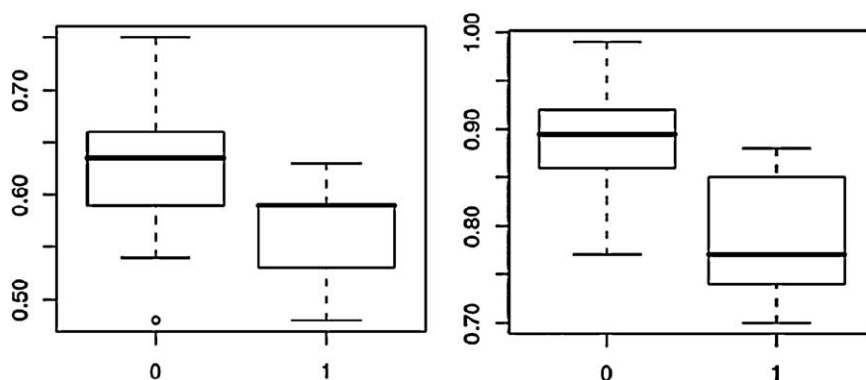


Figure 5 Illustration between the yes (1) and no (0) responses to the glenoid bone substance loss criteria and the Griffiths (left) and Sugaya (right) indexes. The relation is strong for the Griffiths Index ($P=0.001$) and excellent for the Sugaya Index ($P<0.001$) (Mann-Whitney test).

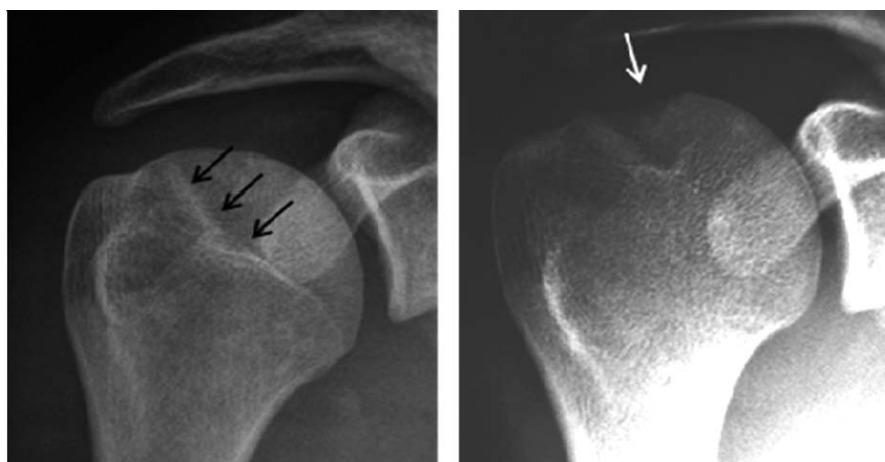


Figure 6 Influence of the beam incidence on the visibility criterion of the Hill-Sachs lesion in maximum external rotation on two images of the same patient taken the same day. Left, the ray is ascendant, masking the notch defect of the humeral head because its intact anterior contour is superimposed, whereas the condensation of the bottom of the notch can be seen clearly (black arrows). Right, the beam is descendant and reveals the notch, which is visible from the loss of posterior head contour (white arrow).

contour [28]. Conversely, the quantitative analysis according to Griffiths and Sugaya demonstrated good or excellent inter- and intraobserver agreement, with intraclass correlation indices greater than 0.9, coming close to those obtained by Magarelli et al. using a CT method comparing the two shoulders [29]. Consequently, there is a contrast between the plain x-ray and CT analyses, which poses the problem of the mediocre sensitivity of isolated AP x-rays in the positive diagnosis of glenoid osseous lesions, a limitation that has already been underscored by other authors [5,22,28]. For the HSL, interobserver reliability of the ISIS analysis of its visibility in maximum external rotation was, in this study, low or very low. This can be explained by the intraobserver reliability that is itself variable and seemingly influenced by the observer's experience. This was not observed for the radiographic measurement of the P/R index for which the reliability values were at a minimum good and most often excellent. The literature reports no studies analyzing the reliability of plain x-rays of the HSL. The quality of the agreement for the P/R index may be related to the better reliability of the internal rotation position, obtained by simply placing one's hand on the stomach. On the other hand, the analysis of the visibility of the notch in maximum external rotation poses two problems: first the variability of this maximal rotation, which can be 70°C for a normal patient and 95°C for a subject with hyperlaxity, with the notch then becoming posterointernal and therefore totally masked by the contour of the anterior and superior humeral head. On the other hand, the visibility criterion of the HSL can be the loss of humeral head contour but also the condensation line at the bottom of the notch, making it just as visible. These two parameters can also vary depending on the incidence of the x-rays (Fig. 6).

For the glenoid, a relation was found between the radiographic visibility of the lesion and its measurement based on the quantitative indices, notably the Griffiths and Sugaya indexes. The threshold value of the index providing a significant relation with the radiological analysis was 0.85, i.e., 15% of the glenoid bone loss, indicating that when the ISIS radiological criterion is negative for the glenoid, bone loss is

less than 15%. However, if it is positive, bone loss is greater than 15%, but a maximum value could not be established. Conversely, no correlation could be established between the visibility of the HSL in external rotation and the P/R index.

5. Conclusion

The analysis of the ISIS glenoid radiological criteria seems sufficiently reliable for daily practice. If the score is positive, bone loss is greater than 15%, although a maximum value cannot be established. In this study, the analysis of the ISIS Hill-Sachs lesion criterion is not reliable. It can be improved using the P/R index and should be completed by CT imaging studies.

Conflict of interest statement

There is no conflict of interest.

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